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Deposition of $FeSi_2$ nano-particle films

$FeSi_2$ナノ粒子薄膜の堆積

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The purpose of this study is to realize quantum dot-sensitized solar cells using silicon-based nano-particles. We have succeeded in structure and size control of Si nano-particles using multi-hollow discharge plasma-enhanced chemical vapor deposition. Here we report generation and deposition of FeSi composite nano-particles, because iron silicide ($FeSi_2$) has a narrow bandgap of 0.8 eV and a candidate material for quantum dot-sensitized solar cells.

1. Introduction

In our previous work we have succeeded in structure and size control of Si nano-particles by using multi-hollow discharge plasma CVD. C-Si and a-Si nano-particles were used as a sensitizer of quantum dot-sensitized solar cells (QD-SCs) [1,2]. Si is abundant resulting in low cost and environment-friendly material as compared with conventional sensitizer materials such as CIGS and CdTe. The conversion efficiency of Si QD-SCs is, however, low because of the band gap of c-Si (1.1 eV) and a-Si (1.7 eV). Therefore it is necessary to find more effective and proper Si compound particles for higher performance of QD-SCs. Here β–Iron disilicide (β–$FeSi_2$) was investigated as a possible candidate because it has a narrow direct band gap of 0.80-0.85 eV [3,4] and a high optical adsorption coefficient of $10^5/cm^2$ at 1 eV. β–$FeSi_2$ films have been fabricated by various techniques such as facing target sputtering (FTS) [5], molecular beam epitaxy (MBE) [6] and magnetron sputtering [7]. Here a magnetron sputtering method was selected for the growth of β–$FeSi_2$ films because it is cheaper and faster than others. $FeSi_2$ nano-particles embedded thin films were deposited as a parameter of pressure and their characteristics were analyzed.

2. Experimental

13.56 MHz RF power generator with a matching network was used for magnetron sputtering. The magnetron sputtering power was fixed at 30 W. Ar gas was supplied at a flow rate of 200 sccm. The pressure was varied from 1.5 Torr to 3.0 Torr. Deposition time was 1 h. The substrate was quartz glass and its temperature was room one. The substrate was positioned at 30 mm from the target center as shown in Fig. 1.

The optical emission spectroscopy (OES) was used to monitor the emission intensities of Ar, Fe and Si.

3. Results and discussion

Figure 2 shows pressure dependence of emission intensities of Ar, Fe, Si (Ar: 696 nm, Fe: 373 nm, Si: 656 nm). The Ar and Si emission intensities were nearly constant regardless of the pressure. The Fe emission intensity decreases linearly with increasing the pressure, because kinetic energy of Ar^+ impinging on the target decreases.

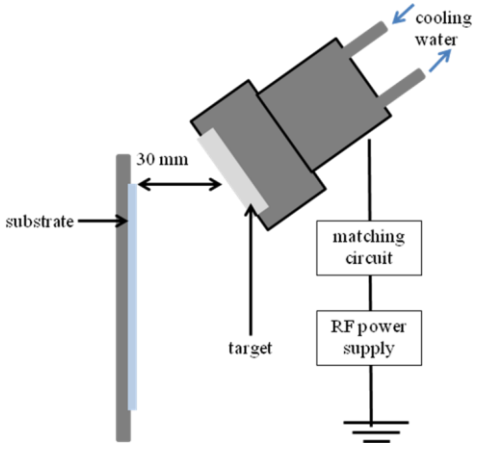

Fig. 1. Schematic diagram experimental setup.

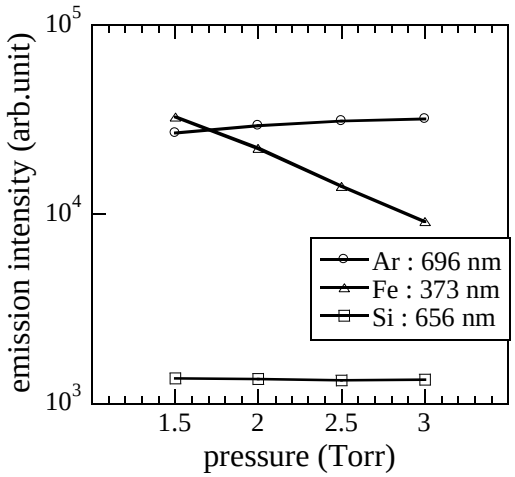

Fig. 2. Pressure dependence of the emission intensities of Ar, Fe, and Si.

The composition ratio was determined by X-ray fluorescence (XRF) analysis. Figure 3 shows dependence of Si/Fe composition ratio on the pressure. Si/Fe ratio increases with increasing the pressure. This tendency is consistent with the results in Fig. 2.

Surface morphology of films was characterized by scanning electron microscopy (SEM). Figure 4 shows a SEM image of film. The mean diameter of particles was 200 nm, 160 nm and 80 nm under 2.0 Torr, 3.0 Torr and 1.5 Torr, respectively. We have succeeded in producing FeSi composite nano-particles by magnetron sputtering.

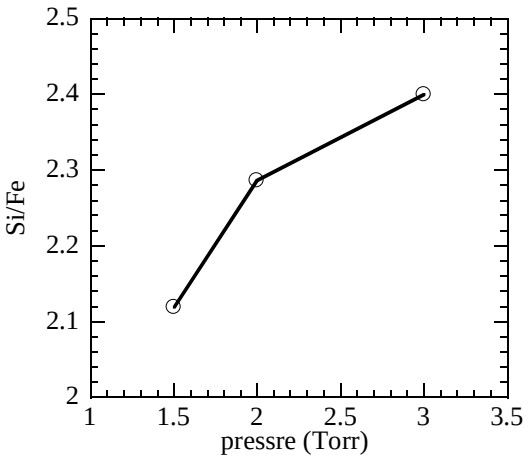

Fig. 3. Dependence of Si/Fe composition ratio on pressure.

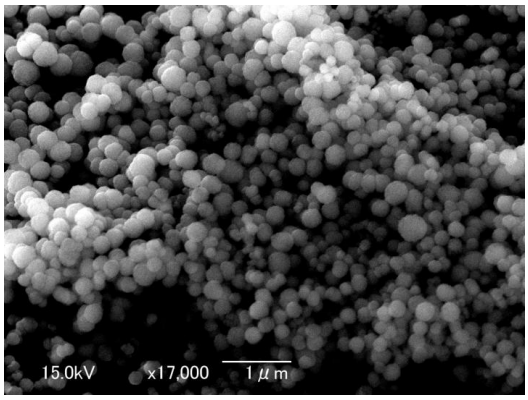

Fig. 4. A SEM image of film.

4. Conclusions

FeSi composite nano-particles were successfully fabricated using the magnetron sputtering method. Si/Fe ratio increases with increasing the pressure. We will apply the FeSi composite nanoparticles to quantum dot-sensitized solar cells.

Acknowledgment

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